Distributed Small Scale Solar Growth in Minnesota

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Abstract

Minnesota's distributed solar generation capacity has grown from almost nothing to over 40 MW in the past decade. Consumer sited solar PV installations have rapidly increased statewide as prices plummeted and state policies that encouraged distributed generation came into effect. While the entire state's solar capacity is increasing, once broken down across different utility service territories the patterns of growth are quite varied. This paper aims to look at the characteristics of regions with higher amounts of customer sited distributed solar generation in Minnesota. Furthermore, it seeks to identify utility specific policies that impact the growth of small scale solar, with a focus on finding implementation methods that are adaptable and equitable as the electrical generation portfolio transforms over the coming decade.

Minnesota has also been an area of focus around clean energy because of its community solar garden statute. While this program is resulting in a large solar boom throughout portions of the state, this paper will not examine the details of that program. Most community solar systems are large systems developed by independent contractors at sites away from the customers they serve. It also falls under different financing and rate structures from customer sited generation, making comparisons between the two types more difficult. It will instead focus on the potential for additional growth in customer sited solar generation that falls under net metering rates throughout Minnesota.

Why Distributed Photovoltaic Solar?

Over thirty nine percent of all new electrical generation capacity added in 2016 was solar energy.[1] Residential solar, which has for past years accounted for over fifty percent of annual installed capacity, fell to nineteen percent of total solar installs, overtaken by utility sized projects.[2] With utility scale solar contributing an ever-increasing percent of generation to the electrical grid, is there still a need and reason for small distributed rooftop solar? Utility scale solar costs far less than roof top installs, although prices continue to decline across all size thresholds. Furthermore, in order to more rapidly transition to carbon neutral forms of electrical generation, utility sized solar brings capacity online more quickly and efficiently.

Minnesota has no fossil fuel reserves and must import any coal or natural gas to run its power plants. Increased small scale solar and wind reduces dependence on outside fuel sources and contributes to the state's economy. Lower fossil fuel use results in carbon emissions reductions and other environmental benefits. As the world deals with the impacts of climate change increasing the amount of clean energy on the grid will position the state to meet its carbon reduction goals. Aside from the environmental benefits, encouraging distributed generation boosts the state's economy and job growth. Solar installers and manufacturers are moving their businesses to the state to take advantage of Minnesota's positive business climate for renewable energy. These benefits are common to all forms of solar energy – utility scale and DG.

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[1] Herman K. Trabish, "As solar booms, utilities look to build new business models with strategic investments." Utility Drive, March 14, 2017.

[2] Ib.

A review of solar cost and benefit analysis studies by the Rocky Mountain Institute's Electricity Innovation Lab classifies the value of solar into five categories: grid services, financial risk, security risk, environmental, and social.[3] Most individuals cite reasons relating to the latter four categories as their primary reasons for installing rooftop solar. It is in grid services that solar holds its greatest potential value, and where it is most under realized as a benefit to electrical generation utilities. From reduced line loss to grid resiliency, there are a whole host of benefits that often go ignored in favor of the flashier economic and environmental benefits. Distributed PV resources encompass these positive externalities to a greater extent than utility scale by virtue of its distributed nature. Having a large number of small systems scattered throughout a distribution system spreads out support services across the grid. As the current system ages incorporating DG as a portion of technical upgrades will transition the electrical system into the 21st century. Distributed small scale solar brings benefits that its larger utility scale counterparts cannot.

Minnesota's Electrical Generation Portfolio

In the past decade Minnesota's electrical generation landscape has shifted dramatically. Coal, once the dominant fuel source for Minnesota's electric utilities, has declined in favor of new sources of electrical generation. While these are predominantly large scale wind and solar resources, customer owned distributed generation is growing as a percentage of the state's electricity portfolio.

Since 1990 Minnesota has increased renewable energy production to over 21 percent of annual electrical generation. While the majority of this energy comes from large scale wind farms, solar is quickly entering the marketplace as well, with close to 500 megawatts of generation forecasted to come online over the next few years.[4] The state's first utility scale solar projects came online in late 2016, and produced almost 30,000 MWh of energy in February of 2017.[5] By comparison, the state's distributed solar produced around 2,700 MWh in the same month.[6] The total amount of solar still only comprise a tiny percent of the state's generation, approximately 0.7 percent in February of 2017.[7] Distributed solar production hit a high in July of 2016, with EIA estimating over 4,300 MWh, an increase of over 1,000 MWh from 2015.[8]

With the jump in renewable energy installation has come a similar decline in coal use. From 2005 to 2015 Minnesota's use of coal for electricity generation dropped to 44.1 percent, an almost 20 percent decline (Figure 1). In 2016 23,484 thousand MWh of the state's total came from coal, down from a high of 35,656 thousand in 2003. Wind production increased 14 percent over the same period, jumping up almost 10,000 thousand MWh a year since 2001. The 2007 Renewable Energy Standard (RES) was a significant factor in the shift towards wind. The success of the RES pushed solar advocates to lobby for a similar solar standard. This has pushed solar into a similar phase of

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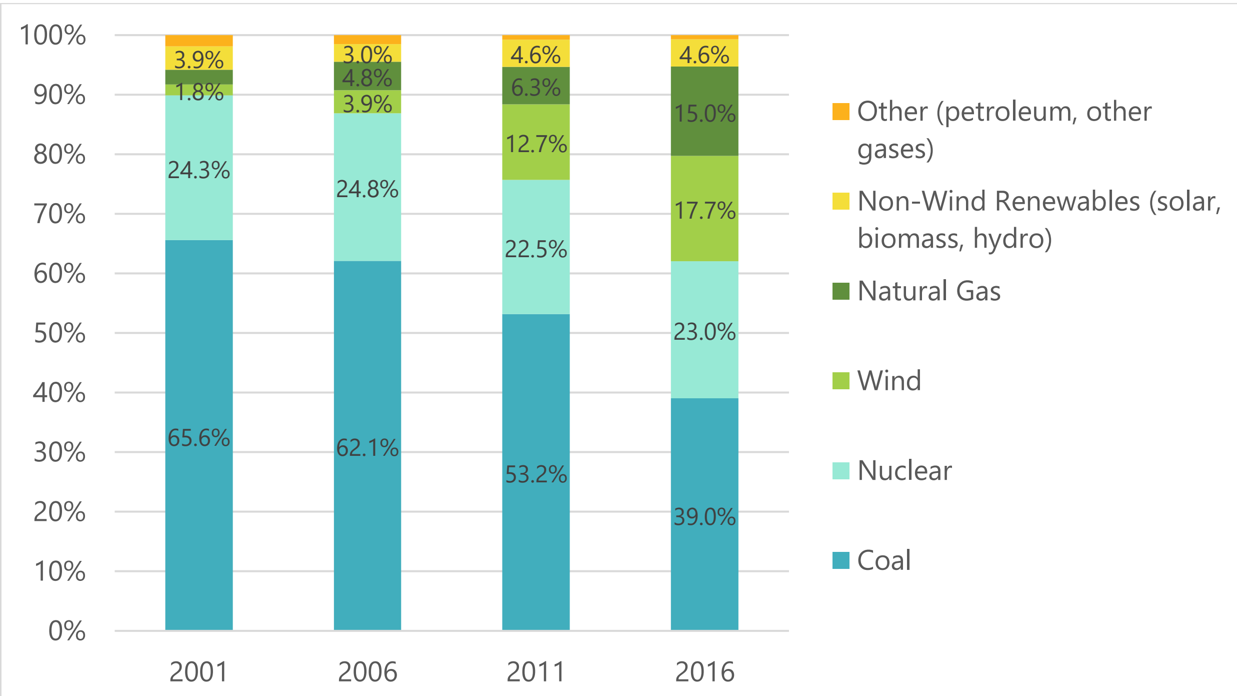
[3] Hansen, Lena; Lacy, Virginia; Glick, Devi. "A Review of Solar PV Benefit & Cost Studies." Rocky Mountain Institute. September, 2013.
[4] Minnesota Department of Commerce. "Minnesota Renewable Energy Update." Minnesota Department of Commerce, April 2016. http://mn.gov/commerce-stat/pdfs/mn-renewable-energy-update-2015-page-numbers.pdf.
[5] U.S. Energy Information Administration. "Net generation for all sectors monthly." Accessed April 28, 2017.
[6] Id.
[7] Id.
[8] Id.

development in the wake of the 2013 Solar Energy Standard (SES) which will require investor owned utilities to procure 1.5 percent of their annual energy from the sun.

Understanding Minnesota's overall electrical generation portfolio is important, as the state's progress on renewables at a high policy level impacts the atmosphere and attitudes in the rest of the state. The forward-looking policies adopted over the past decades in the state have driven changes in utility policies down the chain.

Figure 1: Minnesota Electricity Generation Mix, % of total MWh[9]

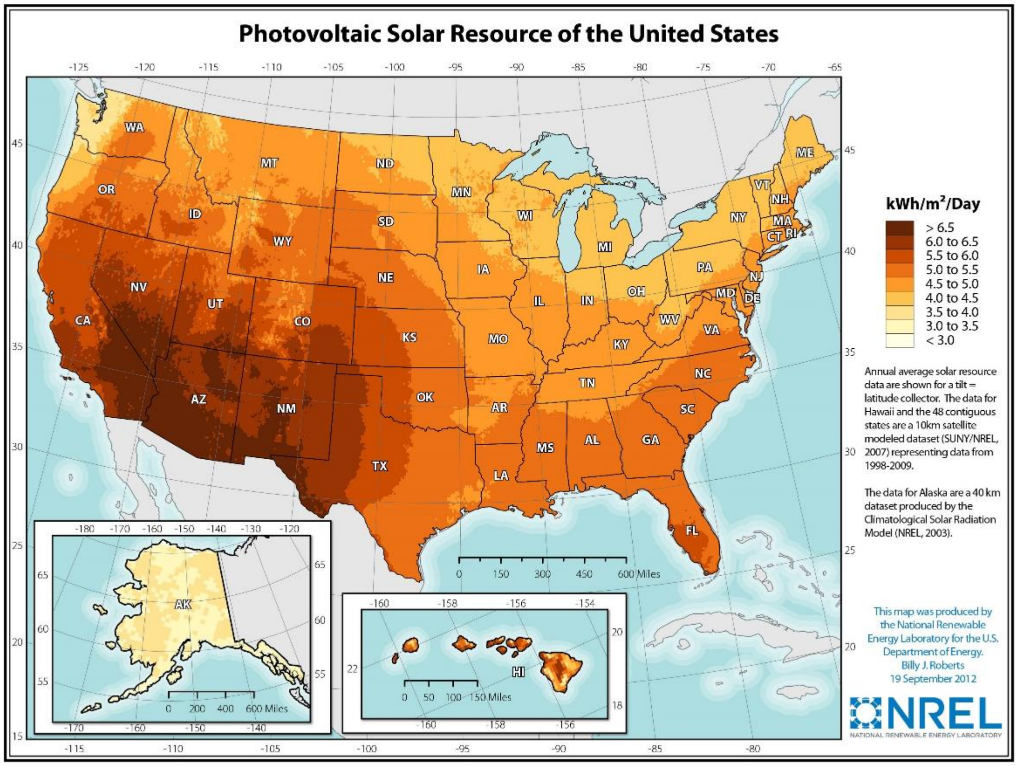


Minnesota's Solar Resource

A common misconception about solar energy in northern areas of the globe is the perceived lack of solar a solar resource. While Minnesota may not be equipped with the hot desserts of Nevada or Arizona, it still receives ample solar insolation to contribute significant amounts of electricity production. Minnesota's solar resource is comparable to other sections of the country that have a much higher penetration of installed distributed generation. Figure 2 depicts the National Renewable Energy Laboratory's (NREL) estimation of solar photovoltaic resource for the United States.

[9] Id.

Figure 2: Photovoltaic Solar Resource of the United States[10]



On a high level, Minnesota's solar resource compares to New York and New Jersey, both national leaders in distributed solar installations. Portions of the state, including the heavily populated Minneapolis-St. Paul metropolitan area have a similar amount of solar resource as New Jersey, which has over 2,062 MW of distributed solar PV installed.[11] By comparison, Minnesota has approximately 42. MW of solar PV.[12] While New Jersey and New York also have implemented additional policies pertaining to distributed solar, it is useful to look at a comparison of high and low penetration states with similar amounts of solar resource. The difference in installed capacity of small distributed PV indicates that Minnesota's solar resource alone is not the only factor impacting the growth of small scale generation. Instead, we must examine economic and political factors that differ in Minnesota from similarly situated states.

It is also worth taking a closer look at Minnesota's solar insolation map (Figure 3), as it presents a more in-depth look at solar insolation data for the state. Collected using LiDAR data by the University of Minnesota, the map below indicates that portions of the state have large amounts of tree cover that somewhat limit the amount of available space for larger solar arrays. Additionally, the northern parts of the state do have somewhat less solar insolation than southern portions. While the

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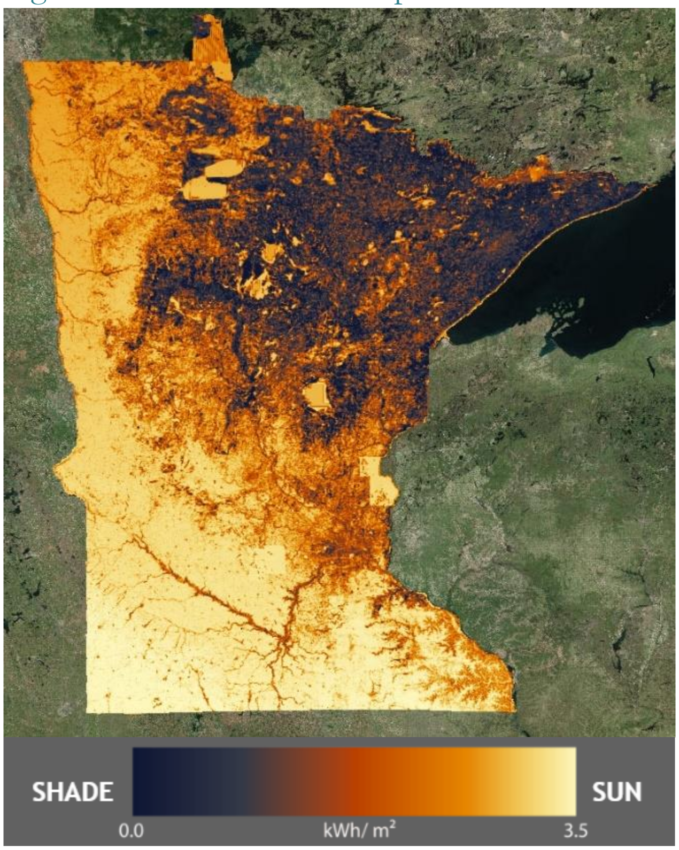
[10] Roberts, Billy J. 2012. "NREL Solar PV US Resource." National Renewable Energy Laboratory. http://www.nrel.gov/gis/solar.html.
[11] http://www.njcleanenergy.com/renewable-energy/project-activity-reports/project-activity-reports
[12] Annual Distributed Generation Reports, Minnesota Department of Commerce Docket No. E-999/PR-16-10
Data compiled March 2017, using historical reports from 2008 to 2016 to confirm accuracy and obtain dates on annual growth patterns. Docket Nos. E-999/PR-9-46, E-999/PR-10-55, E-999/PR-11-10, E-999/PR-11-10, E-999/PR-12-10, E-999/PR-13-10, E-999/PR-14-10, E-999/PR-15-10, E-999/PR-16-10, E-999/PR-17-10

northern portions of the state may be ill suited for larger utility scale solar, it does not pose an undue hindrance to DG. Commercial and residential buildings have rooftops that are not shaded, and as distributed generation is primarily customer driven and customer situated, opportunities are not limited only to the southern portions of the state.

Figure 3: Solar Insolation Map of Minnesota[13]



Minnesota's Utilities

Minnesota has three types of electrical utilities – Investor Owned Utilities (IOUs), Cooperative Utilities (coops) and Municipal Utilities (munis). All utilities in Minnesota are guaranteed exclusive service territories, meaning that they do not share geographic territory with one another. The Public Utilities Commission (PUC) is responsible for electric utility regulation, while the Department of Commerce oversees other related energy programs. Electric utilities play a crucial role in the growth of distributed solar. Their incentive programs, ease of interconnection, and electrical rates all are important components in a consumer's decision to install a solar system.

The Investor Owned Utilities, or IOUs, are the largest electrical service providers in the state. Owned by shareholders, they function as a business and are subject to regulation by the Public Utilities Commission (PUC). Minnesota's IOUs are vertically integrated, meaning they are

[13] Brink, Christopher, Ben Gosack, Len Kne, Yuanyuan Luo, Christopher Martin, Molly McDonald, Michael Moore, et al. 2012. "Solar Insolation, Minnesota (2006-2012)." University of Minnesota. ftp://ftp.gisdata.mn.gov/pub/gdrs/data/pub/edu_umn/atmos_solar_insolation/metadata/metadata.html.

responsible for the generation, transmission, and distribution of electricity to end use customers. In addition to the Cogeneration and Interconnection statutes, the IOUs have additional legislative requirements that encourage the growth of solar energy. In addition to requiring the Investor Owned Utilities to procure 1.5 percent of their energy from solar, the 2013 SES also contains a provision that requires 0.15 percent to come from small scale solar facilities of 20 kW in size or less. Advocates pushed for this provision to encourage greater residential rooftop solar installations. Unlike the RES, the state's cooperative and electric utilities are exempted from the statutory requirements of the SES.

Xcel Energy is the largest utility in the state, serving over one million customers primarily in the Minneapolis-St. Paul metro area. Due to its location in Minnesota's economic and population center, it also has the largest amount of solar PV installations, accounting for more than half of the state's total capacity. Xcel has its own incentive program, Solar*Rewards, that has existed in its current iteration since 2013. The SES included a provision for Xcel to shift its reward system to a production based incentive, where PV customer are paid for each kWh of electricity production. In the original program, initiated in 2008 residences or businesses who installed a DG system received an incentive for each installed kW. This change of program may be a contributor to dip in solar installations in 2013, then a large jump in applications in 2014 after the start of the new program. Xcel is well positioned to meet both portions of the Solar Energy Standard due to their high number of residential installs and large utility scale projects, along with their Community Solar Garden program.[14]

Minnesota Power is the state's second largest investor owned utility and serves the northeastern part of the state, including the City of Duluth. A large portion of its load consist of large industrial customers due to the presence of mining, taconite processes, and forestry in the region. Minnesota Power has 2.2 MW of DG PV, across 186 systems. It recently expanded its incentive program, SolarSense, shifting it to be semi-production based. The amount of the incentive is based on anticipated annual production, but awarded as a lump sum instead of over time. The largest change to the program is the large increase in its annual budget, up nearly half a million dollars from previous years. This is likely an effort to meet the small scale solar carve out of the SES, which at current rates of deployment would be a challenge to meet. As of April 7, 2017, all $530,000 allocated for the current year had be reserved in the application queue[15], indicating a strong response to the new program.

Otter Tail Power is the state's smallest IOU, serving customers in the western half of the state (smaller than some cooperatives). Their customers are primarily situated in small towns with surrounding rural areas served by cooperative utilities. Otter Tail has less than 260 kW of installed solar, a lower number than many of the state's cooperative utilities. Unlike Xcel and Minnesota Power, it does not have its own utility run residential incentive program, but customers can access

[14] Terwilliger, Hanna. November 3, 2016. "In the Matter of Utilities' Annual Reports on Progress in Achieving the Solar Energy Standard." St. Paul: Minnesota Public Utilities Commission.
[15] http://www.mnpower.com/Environment/SolarSense/

Made In Minnesota funding. It is currently proposing "POP" solar (Public Owned Properties) to boost numbers of under 20kW systems and meet the SES standard.

Cooperative Utilities are organized as not-for-profit entities where customers are member owners, electing a board to oversee the utility's activities. With 47 entities, Minnesota has the second highest number of cooperative utilities outside of Texas. Cooperatives originally were formed in the 1940s and 1950s to provide service to rural areas, and as such have customers that are much more spread out than the other types of utilities in the state. The lower density of customers results in higher fixed costs for electricity distribution to maintain the system infrastructure. However, even among the state's 47 coops there are variances in size and customer density. Several of the coops that border on the Minneapolis-St. Paul metro have over 100,000 customers, while other in outstate regions have less than 2,000. These cooperatives provide distribution services to their members, and purchase generation and transmission capacity from a power provider, which in many cases is itself a cooperative. Only Dakota Electric has an incentive program, which is paid out over time to a cap of $4,000. From conversations with utility executives, for many customers installing DG solar, their cooperative is the first point of contact. In this situation, the cooperative is an important gatekeeper of information. If their sources are outdated, or if they are hostile towards DG it could serve as a deterrent to a customer's decision to install solar.

Municipal Utilities function as a branch of city government. They have a public utility commission elected by residents of the municipality that they serve, and are accountable to city regulations. Like coops, they are only subject to limited regulations by the PUC, again with respect to dispute resolution. They also vary greatly in size, from around 100 customers to the City of Rochester with over 50,000 customers. Similar to coops, they are distribution only and purchase their power from municipal power providers (MPAs), distribution cooperatives, or IOUs. However, since they are normally bound within city limits they have a much higher density of customers, resulting in lower fixed costs. Several municipal utilities run their own incentive programs, including Rochester, the state's largest municipal utility.

Trends among distributed generation installation in Minnesota

Distributed generation (DG) refers to small, dispersed systems of energy generation that are not owned by an electrical utility. DG encompasses a wide range of technologies including micro hydro, wind turbines, and diesel generators, but in recent years much of the growth has been in small photovoltaic solar energy systems. Minnesota has numerous laws that both govern and encourage distributed PV, but one of the earliest and most important is 216B.164 – Cogeneration and Small Power Production. Minnesota enacted this statue in 1981 to implement the Public Utility Regulatory Policies Act of 1978 (PURPA). Importantly, when the legislature enacted 216B.164 it applied it to all electrical utilities in the state, not just its Investor Owned Utilities.[16] Most electrical regulation in the

[16] State of Minnesota. 1981. 216B.164 Subd. 2 Cogeneration and Small Power Production. https://www.revisor.mn.gov/statutes/?id=216b.164#stat.216B.164.1.

state only applies to rate regulated utilities, excluding cooperative and municipal utilities. Under Minnesota statue 216B.164, Cogeneration and Small Power Production:

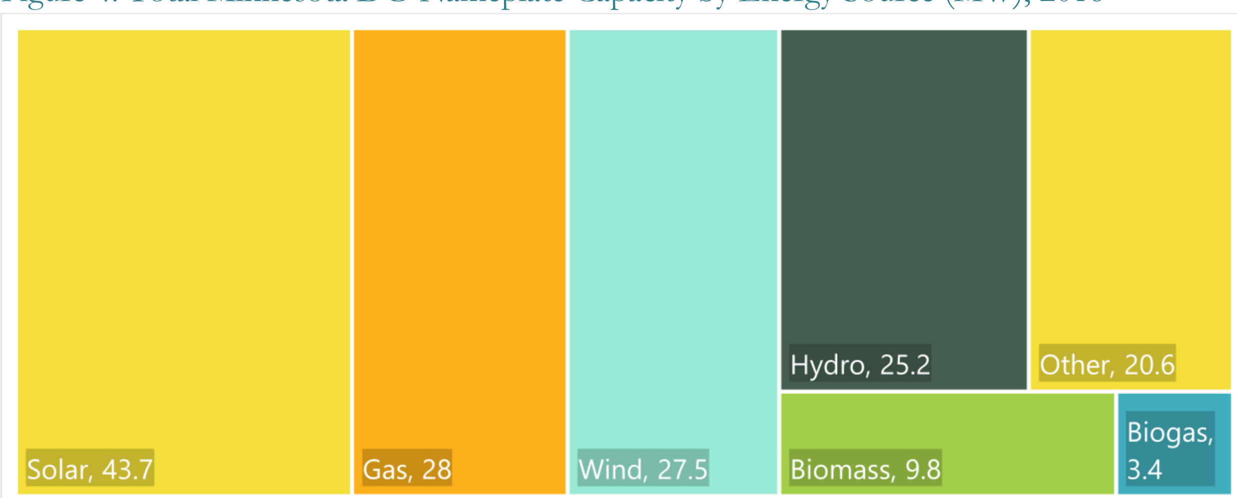
(h) "Distributed generation" means a facility that:

(1) has a capacity of ten megawatts or less;
(2) is interconnected with a utility's distribution system, over which the commission has jurisdiction; and
(3) generates electricity from natural gas, renewable fuel, or a similarly clean fuel, and may include waste heat, cogeneration, or fuel cell technology.

The Cogeneration statute begins with the statement that "This section shall at all times be construed in accordance with its intent to give the maximum possible encouragement to cogeneration and small power production consistent with protection of the ratepayers and the public,"[17] clearly emphasizing the commitment that Minnesota has to promoting customer sited generation.

While there are numerous other statutes that reference renewable energy and distributed generation, it is this definition that sets size limits and fuel types for DG in Minnesota. Figures 4 and 5 depict the current capacity and number of all distributed generation systems in Minnesota.[18] Solar has both the highest number of facilities, and the largest amount of nameplate capacity. Generation data for DG systems is more difficult to capture, as there are reporting inconsistencies among the state's utilities. Solar has the highest nameplate capacity, but since it has a lower capacity factor than other forms of electricity production, the number of MWh generated each year may be lower than other fuel sources. For planning and interconnection purposes, however, utilities count the nameplate capacity of a DG system. The sheer number of solar interconnections completely overwhelms other fuel sources. When discussing DG policies and their benefits, the number of systems is as important as their capacity, since the administrative activities are thus spread across a larger scale.

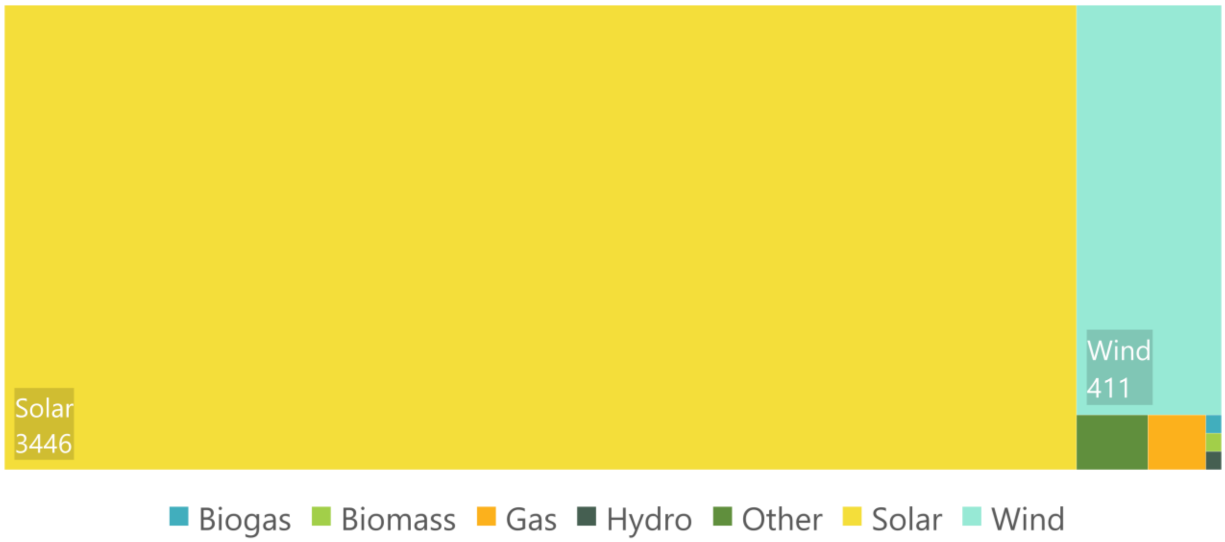
Figure 4: Total Minnesota DG Nameplate Capacity by Energy Source (MW), 2016



[17] State of Minnesota. 1981. *216B.164 Subd. 1 Cogeneration and Small Power Production*. https://www.revisor.mn.gov/statutes/?id=216b.164#stat.216B.164.1.

[18] As reported by utilities in Docket No E999/PR-17-10. A small number of utilities have not reported for 2017, so actual numbers are slightly higher.

Figure 5: Number of DG Facilities by Energy Source, 2016



Prior to small scale wind turbines and rooftop solar, the majority of non-utility generation in Minnesota were diesel or natural gas fired generators which provided backup for critical facilities such as banks and hospitals. In the late 2000s, small scale customer sited wind and solar installations began to pop up throughout the state. Figures 6 and 7 indicate the growth patterns of wind and solar installations since 1986, expressed both as capacity and in number of installations. While wind started out as the largest amount of capacity, it was quickly overtaken in sheer number of installations by solar. In 2016, solar growth continued, adding over 12 MW of new capacity through more than 800 installations.

Figure 6: Minnesota Installed DG Solar Nameplate Capacity, 1999-2016 (MW)

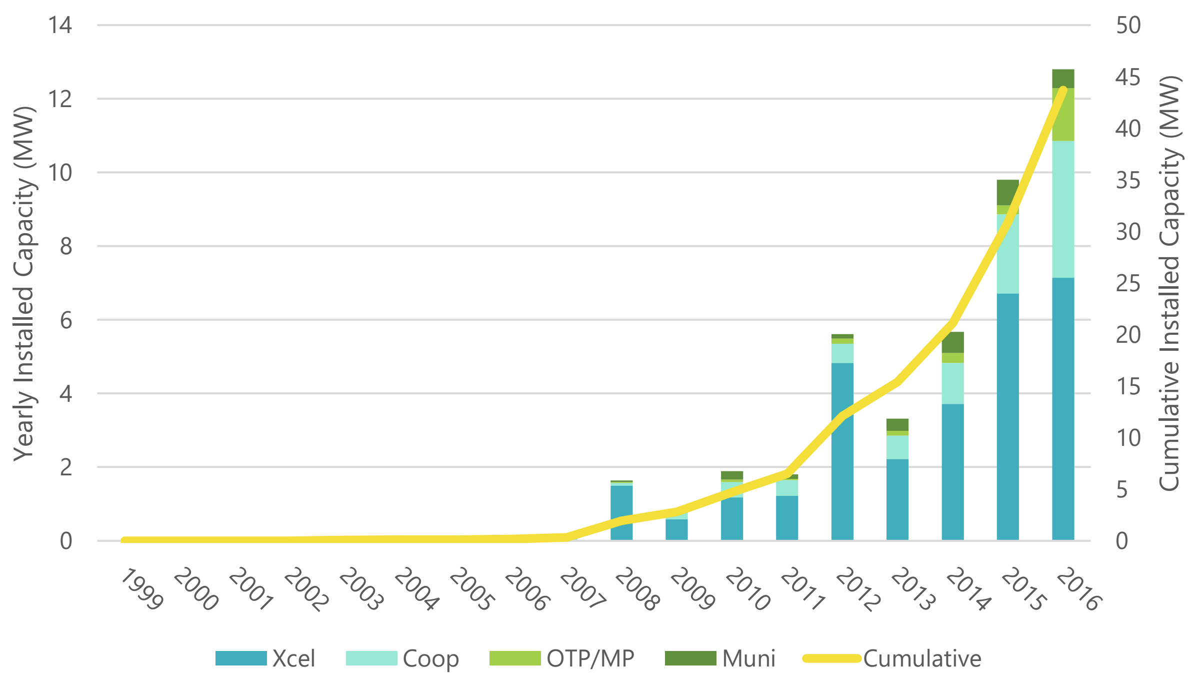
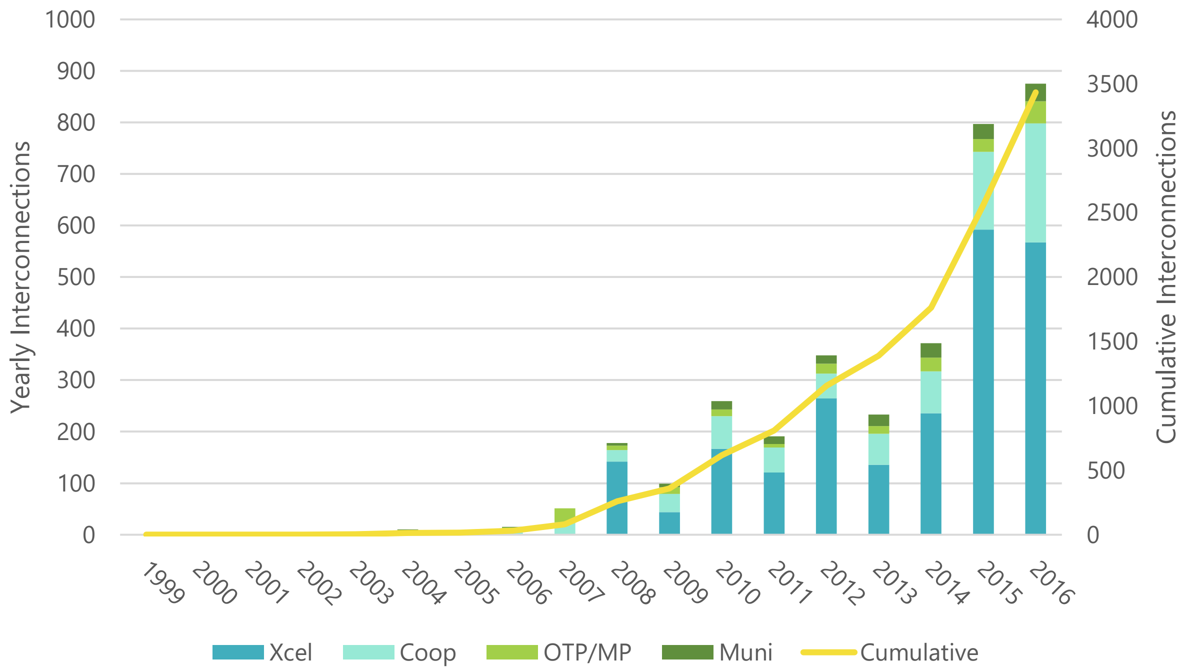
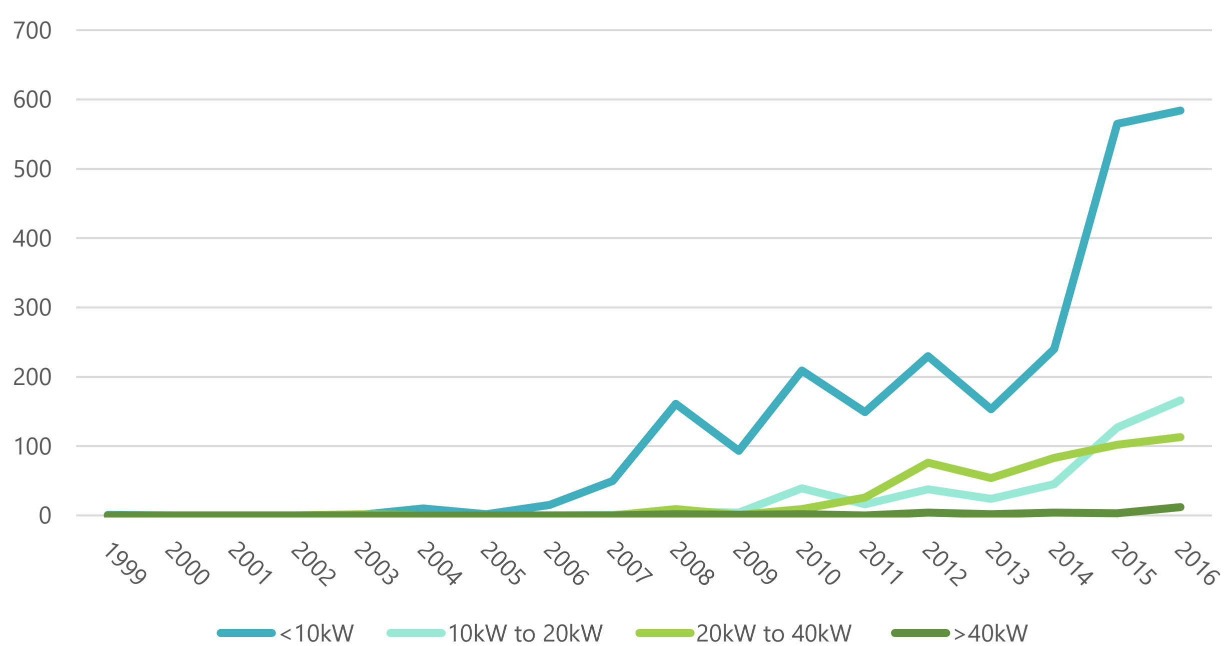


Figure 7: Number DG Solar Interconnections, 1999-2016



In 2015 the state saw its largest jump in interconnections (Figure 8). Most applications fall under 10 kW, but there has been a marked increase in medium sized applications as well. The past year saw modest increases in solar installations over 10kW in size, although interestingly the number of smaller systems remained flat. One possible explanation for the jump in 2015 is the uncertainty surrounding federal tax credits – while they were renewed at the end of 2015, many individuals jumped on the opportunity to install when their renewal was unclear.

Figure 8: Number of DG Solar Interconnections by Size, 1999-2016



Xcel Energy, the state's largest utility, has lead with the most interconnections over the past decade. While it still added a large amount of solar systems in 2016, the number was similar to 2016. In contrast, the state's other utilities increased the number of interconnections during the past year, though not by as large of a jump as in 2015.

Despite having the most solar, Xcel Energy does not have the most DG solar per customer. Renville-Sibley, a small cooperative in the western portion of the state has over 200 watts per customer. The next highest utilities are also outside of the Minneapolis-St. Paul Metro Area.

There have been significant increases in the amount of DG solar in Minnesota, but they do not represent a proportionally large percent of annual generation patterns. DG solar makes up a miniscule portion of Minnesota's annual retail electric sales. No utility has passed the one percent penetration mark, with People's coming the closest at 0.40%[19]

Table 1: Highest Concentrations of DG Solar[19]

Utility Name	Count	Capacity (kW)	Watts per Customer	Customers
1. Renville-Sibley Coop	15	421.31	223.3	1,887
2. Brown Co REA	17	355.675	85.7	4,148
3. Hutchinson Utilities	4	490.5	69.2	7,088
Utility Name	Count	Capacity (kW)	Est. Solar Generation as % of Annual Sales	Annual Sales (MWh)
1. People's Coop	59	850.222	0.40%	279,448
2. Goodhue Co Coop	18	269.7	0.39%	91,435
3. Brown Co. REA	17	355.675	0.33%	139,999
Utility Name	Count	Capacity	Solar Nameplate Capacity as % Peak Demand	Peak Demand (MW)
1. Brown Co. REA	17	355.675	1.66%	21.4
2. Goodhue Co. Coop	18	269.7	1.34%	20.2
3. People's Coop	59	850.222	1.15%	74.2

Geographical Breakdown of DG Solar Capacity

The following maps were developed using ArcGIS and data from the Annual Distributed Generation Reports. Data was compiled from utilities filings dating back to 2007 and summarized by utility and zip code. One important caveat – not all utilities have submitted their annual reports or given zip codes for solar installs. Therefore, some regions of the state do have DG but are lacking enough granularity to accurately represent it on these maps. Other regions rely on previous reports, and may have more DG than indicated.

Figure 8 depicts the zip code level breakdown of DG solar and wind capacity throughout the state. As expected the Minneapolis-St. Paul metro area has high concentrations of solar. However other

[19] Solar and wind capacity numbers from Annual Distributed Generation Reports (Docket No. E-999/PR-16-10). % of total retail sales calculated using a 15% capacity factor from solar and 20% capacity factor for wind. Annual retail sale totals are from the Annual Electric Utility Reports (MPUC Docket No EE-999/PR-16-11)

regions of the state also have large amounts of capacity. The cities of Northfield and Rochester both rank in the top five zip codes in the state for installed capacity. Figure 9 represents the amount of installed DG solar capacity per capita. On a per capita basis installed solar penetration is much more evenly distributed throughout the state. This is preliminary breakdown, since using straight population figures does not always work well for areas that are highly commercial.

Figure 9: Minnesota Distributed Wind and Solar Capacity, 2016

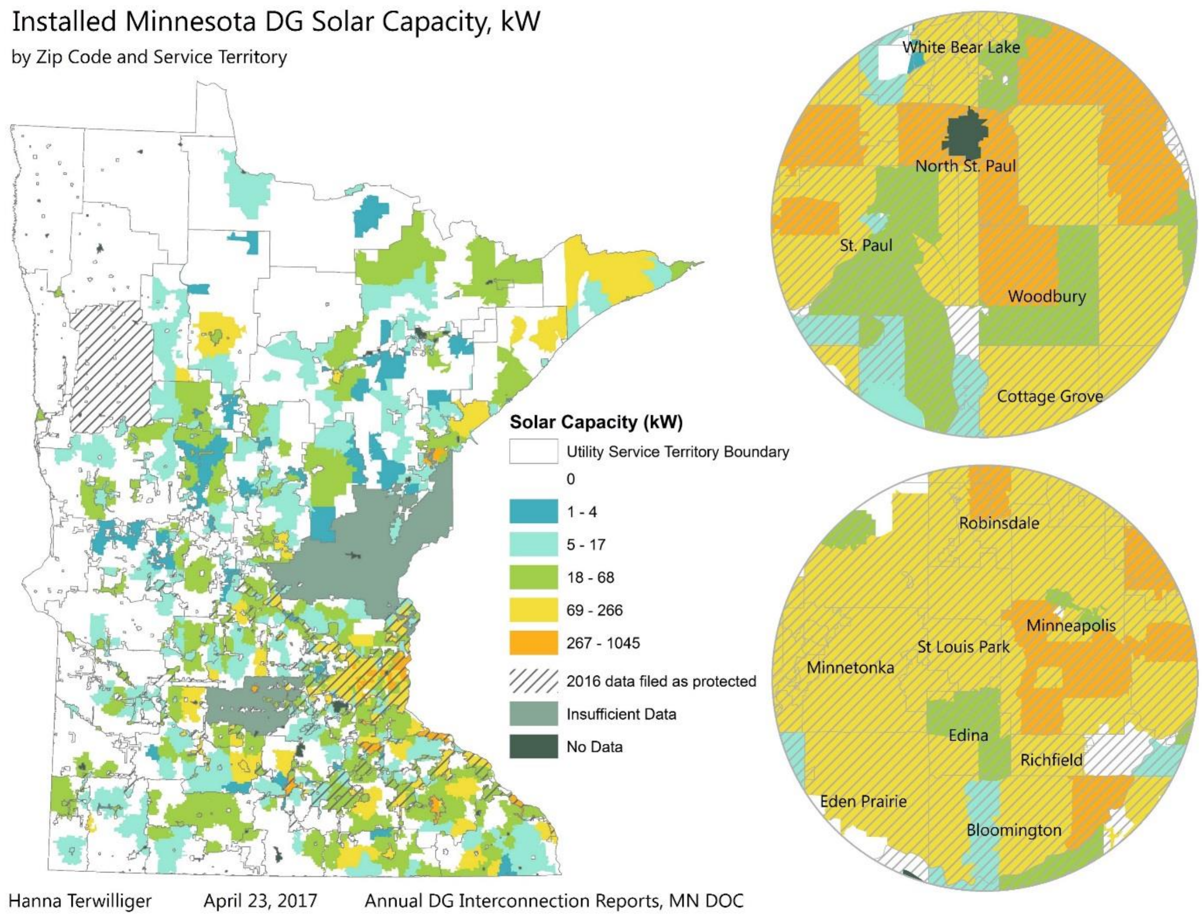
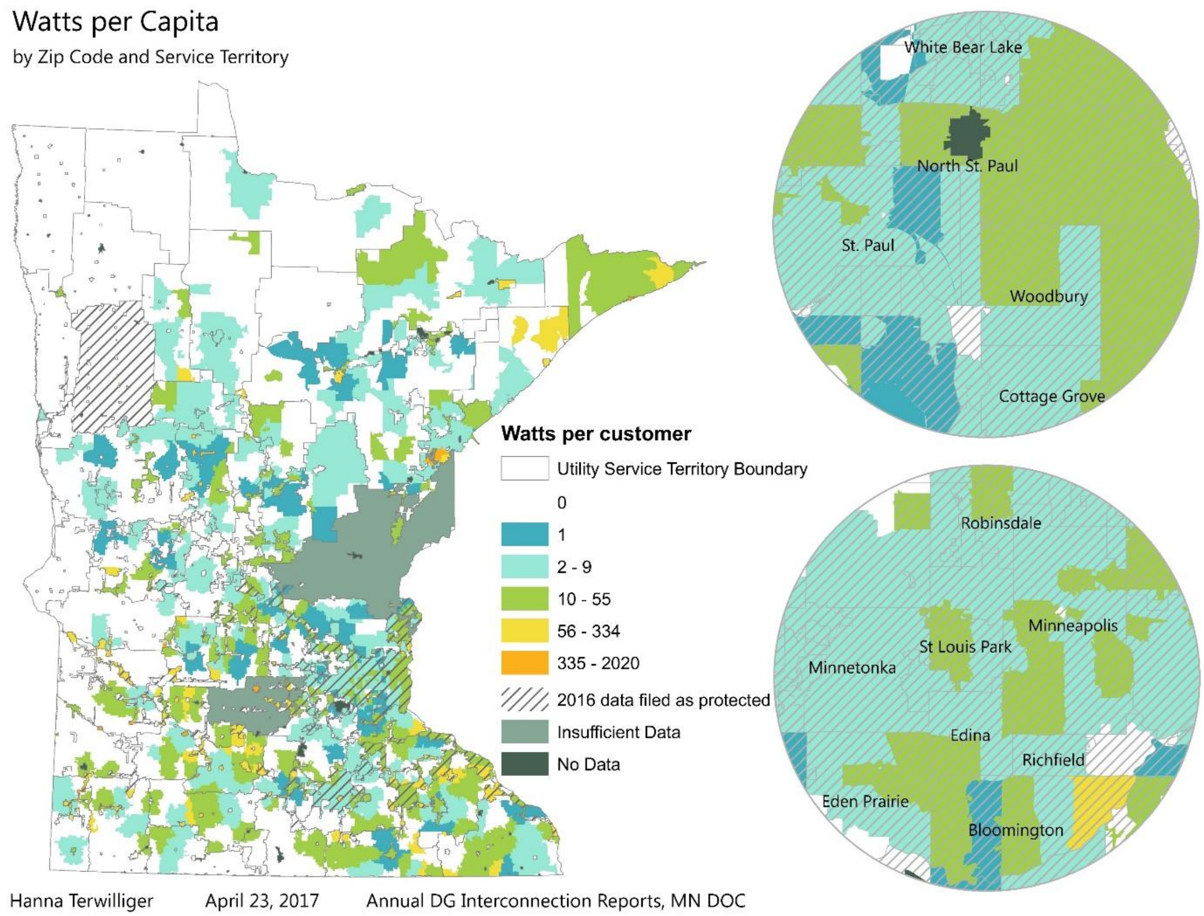


Figure 10: Installed DG Solar watts per capita, 2016



Policies and Politics

Minnesota has a large collection of renewable energy policies that drive renewable energy development. At the federal level, the production and incentive tax credits provide support for both small and large scale developments. At the utility scale, incentive programs like Made in Minnesota and Xcel Energy's Solar*Rewards give small residential and commercial customer additional incentives that drastically reduce the payback period on solar systems. Unlike larger scale wind and solar developments, it is easier to isolate individual policies since some of the state's utilities have implemented them, while others have not. Appendix A contains a detailed list of state and federal policies that impact distributed generation growth.

The 2013 Solar Energy Standard contains a provision that requires 10 percent of the 1.5 percent to come from small scale solar facilities of 20 kW in size or less. Advocates pushed for this provision to encourage greater residential solar installations. While the state's largest utility, Xcel Energy, has sufficient PV installations to meet this requirement, the other investor owned utilities, Minnesota

Power and Otter Tail Power, are so far struggling to meet this requirement.[20] Unlike the RES, the state's cooperative and electric utilities are exempted from the statutory requirements of the SES.

When the Minnesota legislature adopted the Solar Energy Standard (SES) in 2013 there was opposition from the utilities and the state's Republican legislators, as well as some rural DFL members. To get the SES passed, Governor Dayton and metro area DFL members were forced to compromise, exempting cooperative and municipal utilities and reducing the standard to 1.5% of annual generation. With both chambers of the Minnesota Legislature under Republican control, it extremely unlikely that any policies encouraging solar energy will be passed.

In addition to the state's DFL legislators, clean energy and environmental organizations support increasing the state's solar portfolio. For these actors, clean energy is an important tool in reducing the state's carbon emissions to combat global warming. Solar is a way to reduce dependence on fossil fuel sources while creating jobs and economic benefits for the state.

On the opposing side, Republicans believe that renewable resources are overly expensive, decrease reliability, and raise electric rates for consumers. Utilities all bring up these objections, and some see increased distributed generation as a threat to their existing business model. While other utilities may not oppose renewables to quite that degree, they would argue that existing state policy is already sufficient and that the market should drive the push towards renewables, not the state.

While there is opposition to increased solar energy measures, utilities are already complying with the state's energy standards. All utilities are meeting the state's RES, and Xcel is ahead of schedule in meeting its SES goals. In particular, Xcel's Solar*Rewards incentive program has led to a sharp uptick in the number of small scale residential installations. The state's other investor owned utilities, Minnesota Power and Otter Tail Power, are lagging on small solar systems but are rapidly implementing new programs to meet their state requirements. Current policies should continue to drive solar growth, although not at a fast-enough pace to meet our proposed policy of 1.5%.

The PUC has limited authority over cooperative and municipal utilities unless they elect to be rate regulated like an IOU[21]. However, the PUC currently[22] has the power to resolve disputes between Qualifying Facilities and a cooperative utility under 216B.164. In 2015 the state's electric cooperatives successfully lobbied the legislature to change a portion of 216B.164 to allow them to charge fixed fees on distributed generation customers:

> A cooperative electric association or municipal utility may charge an additional fee to recover the fixed costs not already paid for by the customer through the customer's existing billing arrangement. Any additional charge by the utility must be reasonable and appropriate for

[20] Terwilliger, Hanna. November 3, 2016. "In the Matter of Utilities' Annual Reports on Progress in Achieving the Solar Energy Standard." St. Paul: Minnesota Public Utilities Commission.

[21] Dakota Electric is currently the only rate regulated coop in Minnesota.

[22] The Minnesota House and Senate passed House File 234 to remove the PUC's authority to mediate dispute, and instead place it in the hand of a third party. Governor Dayton vetoed the initial bill, but language has been included in the Senate's Omnibus policy bill.

> that class of customer based on the most recent cost of service study. The cost of service study must be made available for review by a customer of the utility upon request.

Since the implementation of that law, around 20 of the state's cooperatives and one municipal utility have adopted fixed fees that range from $1.30 a kW to $5.68 kW. Aside from one coop, all the fees are calculated based on a methodology developed by the Minnesota Rural Electric Association, and are under review by the PUC.

Most municipal and cooperative utilities are much smaller than their investor owned utility counterparts. They lack many of the staffing and financial resources of larger utilities, making rapid changes difficult and expensive. Likewise, their smaller networks of customers mean that a larger infrastructure change is felt more closely across many their customers. A portion of these fixed costs are recovered in their electrical rates, instead of solely as a fixed monthly charge. They contend that as the number of distributed generation customers grows, they are no longer paying for that portion of fixed system costs embedded in their rate since they are no longer purchasing electricity. Since these DG customers are still relying on the grid, utilities argue that customers must be charged for their portion of grid maintenance through an additional monthly fee. Many cooperatives feel that distributed generation customers, and in particular small solar customers, are no longer paying a proportional amount. On the other side of the equation, DG customers oppose fixed fees as a cost prohibitive barrier to DG production. They assert that solar, wind, and other forms of DG benefit the grid through reduced line losses, peak demand reduction, and grid resiliency and that these benefits are not properly compensated once fixed fees are implemented under a net metering structure. The stated point of conflict between the two groups is how to pay for fixed systems costs without unfairly saddling either DG customers or other consumers with disproportional shares of costs.

Adding to this problem is the lack of a size to load ratio in Minnesota's net metering statue. Under current state law, an individual can install a DG system up to 40 kW in size and receive net metering, even if their annual usage is only 5 kW. Until recently, the large upfront cost of solar meant that this would be cost prohibitive, but as prices have fallen some consumers see an opportunity to capitalize on this provision. The state's investor owned utilities have limited system sizes to 120% of annual load as a condition of receiving their incentive program, but in the absence of that kind of arrangement, individuals are free to install any size system.

Cooperative utilities are not necessarily hostile to renewable energy (as many would like to have their own sources of generation to rely less heavily on their generation and transmission suppliers) but do not like customer sited generation as it could erode their current business model if penetration levels were to someday increase to levels similar to other areas of the country. It is also important to note that there is a wide variation among the state's cooperative utilities support of DG. While some are skeptical or hostile to the current status of DG solar, many are taking steps to adapt and embrace forward looking policies that help them adapt to the changing energy landscape.

National Policies and Trends

One incentive for DG that is constant across all of Minnesota's utilities is the federal Investment Tax Credit (ITC). Both business and residential customers can claim a thirty percent tax credit off the installed cost of a variety of renewable energy systems. Originating in the Energy Policy Act of 2005, the ITC has been extended and expanded multiple time. Most recently, the 2015 Consolidated Appropriations Act extended the full ITC for solar through 2020, with a gradual drawdown to ten percent by 2022. The table below describes the various step-downs for different technologies.

Table 2: ITC Drawdown[23]

Technology	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**Future years**
PV, Various Solar Thermal	30%	30%	30%	30%	26%	22%	10%	10%
Hybrid Solar Lighting, Fuel Cells, Small Wind	30%	-	-	-	-	-	-	-
Geothermal Heat Pumps, Micro turbines, CHP	10%	-	-	-	-	-	-	-
Geothermal Electric	10%	10%	10%	10%	10%	10%	10%	10%
Large Wind	30%	24%	18%	12%	-	-	-	-

The ITC translates into measurable savings for small solar systems, bringing the cost into financial realty for a larger portion of the population. This has been a major factor in driving nationwide growth in DG systems. Table 3 depicts the average savings for a Minnesota resident installing solar.

Table 3: Average ITC savings for Minnesota residents on small solar systems, 2015[24]

	5 kW System	10 kW System	20 kW System	40 kW System
Price before tax incentive	$23,885.80	$47,771.60	$95,543.20	$ 191,086.40
Price after tax incentive	$16,720.06	$33,440.12	$66,880.24	$ 133,760.48
ITC Savings	**$7,165.74**	**$14,331.48**	**$28,662.96**	**$57,325.92**

With the change in presidential administrations, the fate of the tax credits is uncertain, although the most recent renewal at the end of 2015 attracted bipartisan support, including Minnesota's congressional delegation.

Another nationwide factor has been the rapid drop in the installed price of solar. The most recent report by the National Renewable Energy Laboratory found that solar prices have continued to decline through 2016 (Figure 11).

[23] "Business Energy Investment Tax Credit (ITC)"

[24] Calculated using 2015 Annual Distributed Generation Reports, MN Department of Commerce. Installation cost before incentives was divided by total system size, then averaged across utilities and all system sizes for an average statewide per kW cost of $4,777.16. This was then multiplied across various system sizes.

Figure 11: NREL Cost Declines for Solar Prices[25]

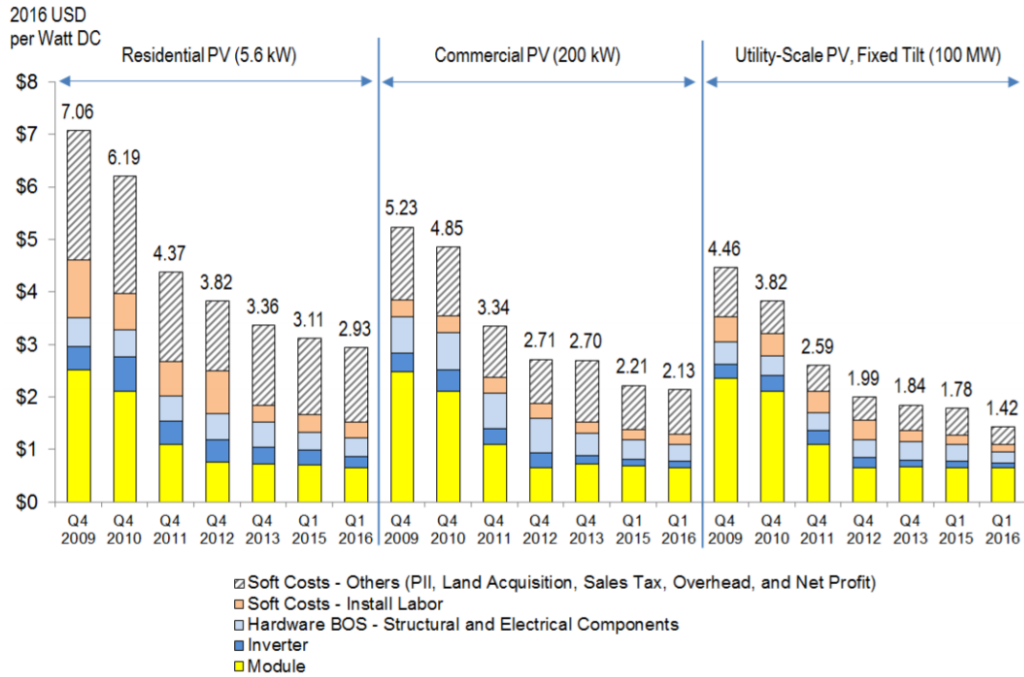


Figure ES-1. NREL PV system cost benchmark summary (inflation adjusted), Q4 2009–Q1 2016

This represents a nationwide average drop of $4.13 per watt since 2009, or over $23,000 for the average US system. Hardware costs have been the largest source of price drops, with solar panel modules and inverters seeing large declines. Decreasing soft costs will be an important step to further reduce the cost of installing solar. Soft costs include the price of permitting, inspections, and labor. Larger projects spread out the soft costs across a greater amount of capacity, achieving better economies of scale. For example, processing an application may have a flat cost of $100, but that will be a much larger proportion of a 3kW system than a 1 MW system. Soft costs vary more than hardware costs depending on local regulations and labor costs. Outdated interconnection standards, restrictive permitting, and system employees new to processing solar installs can all drive up soft costs. Installation prices across Minnesota still have variations, but these are spottily reported through the annual DG Interconnection reports, and as such are not a good variable to include in the regression analysis.

Regression Analysis

I looked at two units of analysis: a zip code level breakdown, and a utility service territory breakdown. The utility scale breakdown analyzed the differences in utility level policy across the state's electric companies. At the zip code level, the regressions look at demographic and societal factors.

[25] Fu, Ran, Donald Chung, Travis Lowder, David Feldman, Kristen Ardani, Ran Fu, Donald Chung, Travis Lowder, David Feldman, and Kristen Ardani. 2016. "U. S. Solar Photovoltaic System Cost Benchmark: Q1 2016 U. S. Solar Photovoltaic System Cost Benchmark: Q1 2016." *National Renewable Energy Laboratory*, no. September.

Hypothesis

For the utility level regressions, I selected four variables that I suspected would have an impact on the amount of distributed generation.

1. Incentive Program – the presence of a financial incentive for DG solar customers will lead to more solar installations, as it will lower the overall cost.
2. DG Fee – utilities with a fixed charge on DG systems will have a lower amount of solar than those without, as a monthly fixed fee will drive down the financial savings.
3. Presence of Community Solar Garden program – having an alternative to installing solar on their own property will lower the amount of customer sited DG.
4. Average Electric Rate – higher electric rates will result in higher amounts of DG as there is more incentive to lower energy costs through private generation.

For the zip code level regressions, I selected five demographic characteristics that I theorized would have a positive impact on the amount of DG solar in a geographic region, along with incentive program and average electric rate from the utility scale analysis.

1. Per capita income – individuals with more money can afford the upfront cost of solar through access to capital.
2. Percent home ownership – areas with higher rates of home ownership will increase the amount of properties available for solar installs, since renters are unable to install solar.
3. Home value – individuals with a lower property value are less likely to put in a solar system that is valued at a large percent of their residence's cost.
4. Education – individuals with higher levels of education are more likely to install solar because they are more likely to believe in climate change and are aware of the financial benefits of installing solar.
5. Political/climate change attitudes – individuals who believe in climate change and support regulating carbon emissions from existing power plants are more likely to install solar due to personal values.

Data Set

The primary data source for this analysis comes from the Annual Distributed Generation and Interconnection Report filed since 2007 with the Minnesota Department of Commerce and Minnesota Public Utilities Commission[26]. Each electric utility in the state is required under Minnesota Statute 216B.1611 to report data related to the interconnection and disposition of all distributed generation systems operating in parallel with the utility's system. Data from these reports was compiled into a single data set during the summer of 2016, with updates in March of 2017. Each utility submits a separate report in the state's eDocket's system. Each utility's report was combined into a single large data set. Where information was missing from certain utilities, attempts were made to cross reference with reports from previous years, as well as data from the Qualifying Facilities Reports.[27] Much of the information in the reports is collected from the system owner during the

[26] Docket Nos. E999/PR-17-10, E999/PR-16-10, E999/PR-15-10, E999/PR-14-10, E999/PR-13-10, E999/PR-12-10, E999/PR-11-10, E999/PR-10-55, E999/PR-9-46

[27] Docket Nos E999/PR-17-09, E999/PR-16-09, E999/PR-15-09, E999/PR-14-09, E999/PR-13-09, E999/PR-12-09, E999/PR-11-09, E999/PR-10-09, E999/PR-9-54

interconnection process, meaning that sometimes system information is reported in AC and sometimes in DC without any indication in the report. Therefore, overall capacity information could be higher or lower.

One of the largest problems with doing an in-depth analysis of the state's solar capacity is the lack of consistent granular geographic units. Minnesota's utility service territories do not line up with other common geographical markers like zip codes, county lines, or city boundaries. Furthermore, the data reported in the Annual Distributed Generation Reports only contains city and zip code as the approximate location for reach install. The zip code level is therefore the most granular data available, but still needs manipulation to allow for the analysis to include utility specific characteristics. Each utility's service territory was broken down into zip code units using the intersect feature in ArcGIS. Where one zip code contained multiple service areas ArcGIS divided them along the shapefile feature lines. Once Minnesota was divided into geographical areas by utility service territory and zip code ("service zip"), I calculated the area of each shape. Then, using data from the 2014 ACS I proportioned demographic characteristics to each service zip area based on the percentage of the zip code's territory that it contained. For example, 23.7 percent of zip code 55008 lies in Connexus's service territory, while the other 76.3 is in East Central's. Therefore, I apportioned the corresponding percentages of the entire zip code's population to each subdivision (Table 4). Similar methods were used for other data points. Where the statistic was in a percentage format, the same value was used for all subdivisions of a zip code.

Table 4: Example of Zip Code Manipulation

	Zip Code	% Zip Code Area	Population
Connexus Energy	55008	23.7%	3567
East Central Energy	55008	76.3%	11514

I faced a similar problem for the Political and Climate Change score variable. Originally, I wanted to use a region's attitude towards climate regulations, and in particular regulations on carbon emissions from power plants as a variable. However, the Yale Study on Climate Change Communications only contains data specific at the county level in Minnesota, which was not granular enough for my regression. Instead I decided to combine the data from the Yale survey with elections data from Minnesota's election results. I used the past three state level elections for the Minnesota House of Representatives, looking at the results down to the precinct level. This was a way of determining a region's political ideology at the most granular level. I broke down the election results into the zip code units created above, again using the intersect feature in ArcGIS. When one zip code unit contained multiple precincts, the average for the entire zip code was taken as the value. After each zip unit had an assigned political score, it was averaged with the county level support for carbon emission regulations from the Yale climate survey, creating the final value.

Appendix C gives a more detailed breakdown of data sources for all variables.

Limitations

Since the Annual Reports that form the basis of this analysis's data set are reported by utilities, there is missing information that results in differing numbers of observations across the regressions. There are two common sources for missing information. First, utilities that have never reported their annual reports, mainly small municipal utilities. Second, two utilities, East Central Energy and McLeod Cooperative Power Association did not report the DG system's location, which makes it impossible to include them in a geographically based regression analysis. Wild Rice Electric Cooperative classified all individual system data as protected, and is not included in the geographically based regression analysis.

There are several utility policies that were beyond the scope of this analysis, but should not be ignored. These would all be valuable subjects for expanding this research in the future.

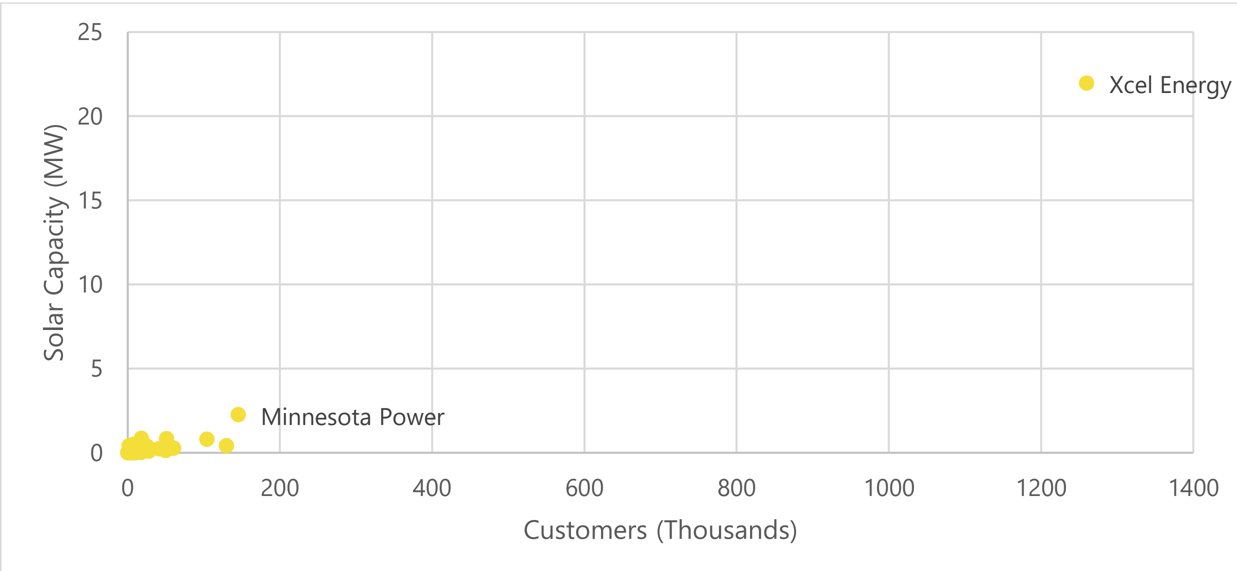
1. Interconnection Information Availability: The ease with which utility customers can access information about interconnecting a DG solar system could have an impact on the amount of solar in each area. However, to figure out what each utility does and does not have available would take extensive searching through utility websites and coding of the data. A brief review showed a wide range – some utilities had the state's interconnection standards, FAQs, and utility specific information easily accessible from the website, while others had nothing.
2. Attitudes of Utility Leadership Towards DG Solar: Difficult to quantify without a qualitative analysis. One option could have been to look through member newsletters and board policies, but the amount of time required would be enormous.
3. Proximity to Solar Installers: No easily accessible data base with location information in a readily accessible format for GIS analysis. There is also the problem of how to set geographic areas for where an installer is active, and how to determine the level of advertising they are doing in each region.
4. The only demographic data was pulled from the census records. There could be additional characteristics that are important that are not included.
5. This analysis does not differentiate between residential and commercial installs, but the motivations may be different for a business customer than a residential customer. Furthermore, additional financial assistance may be available for business customers.
6. All utility policies were coded as dummy variables due to the difficulty of comparing different units of analysis for their financial portions, along with information that had not been submitted for 2016.

Utility Service Territory

The utility analysis used Minnesota's 178 electric utilities as the unit. However, only 122 had sufficient information for all variables to perform the required analysis.

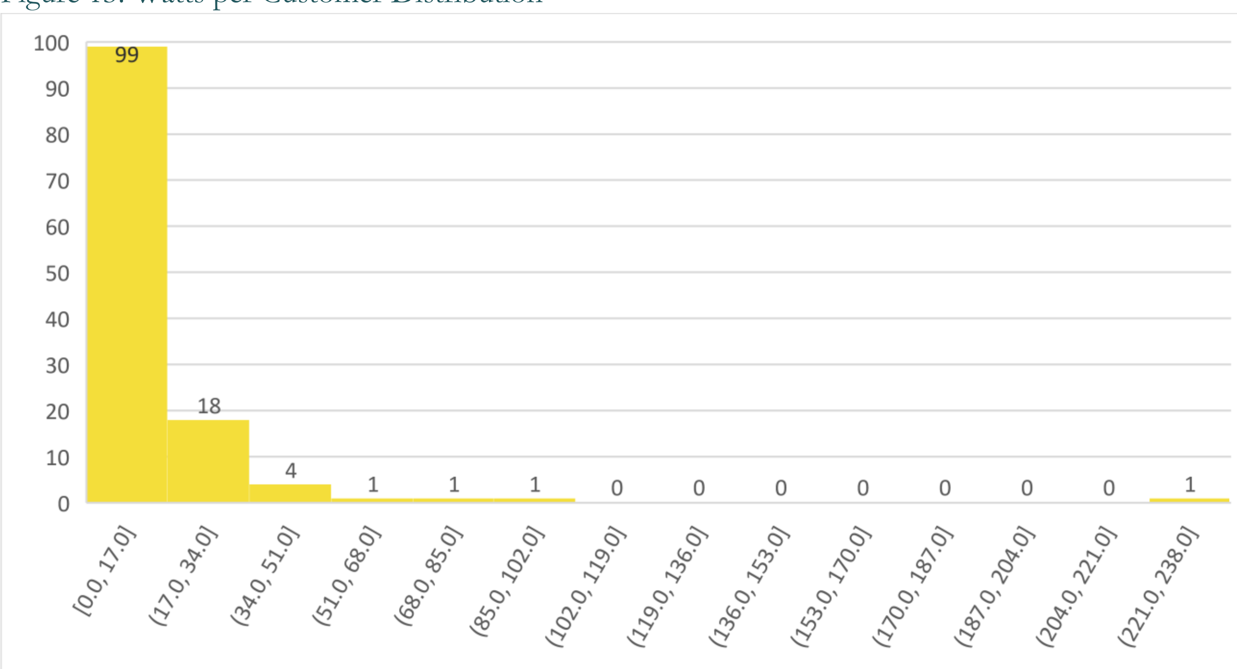
I ran one model based on the data set at utility scale. Since Xcel has both the largest number of customers along with the highest percentage of solar energy, it can bias the estimated relationships among other utilities (Figure 13). It was important to weight the model to number of customers and to use watts per capita as the unit of analysis.

Figure 12: Solar Capacity (kW) vs Utility Customers



Once solar capacity was weighted on a per customer basis, Xcel no longer stood as an outlier. Instead, a small cooperative from western Minnesota, Renville-Sibley Cooperative, had a watts value that was much higher than any of the other utilities. I ran my regression models both with and without Renville-Sibley.

Figure 13: Watts per Customer Distribution



My goal was to look at the effect of three types of utility policies and their impact on total solar capacity: the presence of a utility run incentive program, the opportunity to subscribe to a community solar garden, and the presence of a distributed generation fee. I included an additional variation to look at the effects of the average electric rate on the amount of solar capacity. In each instance the utility policy was treated as a dummy variable. I then looked at the marginal effect of each policy to see which had the greatest impact on solar capacity. After running a correlation on the variables, utility type had a strong enough correlation with DG policies that it was not included as a control variable.

I initially ran each model as a bivariate regression to determine directionality and individual significance (Table 4). Next, I ran models with a combination of utility policies (Table 5).

Table 5: Bivariate Regression Results, Utility Level

Variable	All Utilities				Renville Sibley Omitted			
	Model 1a	Model 2a	Model 3a	Model 4a	Model 1b	Model 2b	Model 3b	Model 4b
Incentive Program	5.46** (1.91)				5.90*** (1.58)			
CSG Available		5.77** (2.02)				6.31*** (1.67)		
DG Fee Present			0.30 (2.80)				0.48 (2.36)	
Average Electric Rate				-93.66 (65.16)				-6.75 (55.16)
Constant	10.49*** (1.54)	9.91*** (1.70)	13.97*** (1.01)	23.44** (6.63)	10.05*** (1.27)	9.37*** (1.41)	13.79*** (0.86)	21.59*** (5.61)

***P<0.01, **P<0.05, *P<0.1, (Standard Error)

Table 6: Linear Regression Results, Utility Level

Variable	Model 5	Model 6
Incentive Program	6.53** (2.02)	6.97** (2.20)
CSG Available	3.62** (1.82)	3.65** (1.82)
DG Fee Present	5.34** (2.63)	5.23* (2.65)
Average Electric Rate		30.47 (60.58)
Constant	6.37*** (1.66)	3.01 (6.88)

***P<0.01, **P<0.05, *P<0.1, (Standard Error)

In the bivariate models, standard error decreased once Renville-Sibley was omitted. The following analysis is based on Models 1b-4b and Models 5 and 6, using a significance threshold of p<0.05. As expected, the presence of an incentive program results in a 5.90 watt per capita increase in installed capacity in the bivariate model. It increased even more once all policies were included in the multivariate regression, up to 6.97 watts per customer.

The presence of a DG fee was only significant in model five, but its positive presence was surprising. Imposing an additional fee on DG solar customers makes the economics more unfavorable, lessening system payback. In this instance it could be an indication of reverse causality in the model. Utilities that have higher amounts of DG may be more likely to institute a fee to mitigate perceived cross-subsidization effects. Alternatively, customers putting in solar may not be deterred by the fee as they still wish to have a system for other benefits.

The presence of a Community Solar Garden went against my hypothesis, but this is not entirely surprising. Utilities that are seeing a large amount of interest in DG may also decide to develop a Community Solar Garden in response to member needs, and to provide a utility controlled option. Alternatively, customers may be exposed to solar through a utility's CSG program and investigate owning their own system instead.

One important factor to consider is the relatively short lifespan of many policies. Both community solar gardens and distributed generation fees are recent policy developments, and redoing the analysis in future years may grant more accurate insight. As the policies are in place for longer periods of time, their impact will become better known. Especially in relation to DG Fees, utilities are still in the process of implementing the policies, meaning that there could be more of a chilling effect on DG as time progresses. Rerunning the models either as a time series or in the future once the policies have been in place may provide a more accurate picture.

The utility scale is useful for looking at the cumulative impact of different policies. However, within each service territory there are variations in other demographic characteristics that impact the amount of solar capacity. In the following models, geographically granular regressions help to distinguish which societal factors are indicators of high DG solar growth regions.

Zip Code Level

One of the most important factors to control for was population. Areas with large populations have by default more individuals, and therefore a larger number of potential solar adopters. I divided a zip region's solar capacity by its population, and then weighted the sample to minimize the size effect, similar to the utility model. As in the utility level models, the three types of utilities in Minnesota had strong correlations with some of the variables, and were not included as control factors.

Initially, I individually regressed solar capacity on all variables to determine directionality and individual significance (Table 6). My next step was to develop models based on factors that I theorized would impact the amount of solar development. I ran multivariate linear regression using the variables from above in a number of combinations (Table 7).

Table 7: Bivariate Regression Results, Zip Code Level

Variable	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12	Model 13
Bachelors or Graduate Degree (%)	0.06* (0.04)						
Income per Capita (Thousand $)		0.03 (0.04)					
Owned Household (%)			-0.07** (0.02)				
Median Home Value (Ten-thousand $)				0.02 (0.06)			
Political and Climate Change score[28]					0.03 (0.05)		
Incentive Program (Dummy)						5.43*** (0.73)	
Average Electric Rate (cents)							-1.80*** (27.99)
Constant	5.19*** (0.87)	5.60*** (1.29)	11.66*** (1.83)	6.17*** (1.15)	4.73 (2.98)	3.57*** (0.54)	25.24*** (2.93)

***P<0.01, **P<0.05, *P<0.1, (Standard Error)

Table 8: Linear Regression Results, Zip Code Level

Variable	Model 14	Model 15	Model 16	Model 17
Incentive Program (Dummy)	8.27*** (0.94)	7.42*** (1.17)	8.39*** (0.95)	7.54*** (1.19)
Income per Capita (Thousand $)	0.19** (0.08)	0.18** (0.08)	0.24** (0.11)	0.22** (0.11)
Political and Climate Change score	-0.44*** (0.08)	-0.42*** (0.08)	-0.43*** (0.08)	-0.41*** (0.08)
Owned Household (%)	-0.11** (0.03)	-0.10** (0.03)	-0.12** (0.04)	-0.11** (0.04)
Median Home Value (Ten-thousand $)	-0.28** (0.11)	-0.27** (0.11)	-0.27** (0.11)	-0.26** (0.11)
Bachelors or Graduate Degree (%)			-0.06 (0.09)	-0.05 (0.09)
Average Electric Rate (cents)		-0.44 (0.35)		-0.43 (0.35)
Constant	33.67*** (5.51)	37.13*** (6.23)	33.25*** (5.55)	36.67*** (6.29)

***P<0.01, **P<0.05, *P<0.1, (Standard Error)

[28] Average of voters that supported DFL State House Candidates in the past 3 elections, averaged with the percent that support carbon regulations on existing coal fired power plants (from Yale Climate Change Communications data)

Many of the variables were not significant at the $P<0.05$ threshold in the bivariate regressions. The presence of an incentive program had the greatest impact, raising the per capita installed solar capacity for a region by 5.43 watts. This tracks with the results from the utility scale regressions where the presence of an incentive program also increased the per customer installed solar capacity by a similar magnitude. Incentive programs continued to have a strong positive impact on solar capacity across all models in the multivariate regressions.

Unexpectedly, as home ownership rates rose, the amount of solar decreased across all models. I initially selected Home Ownership Rate along with Median Property Value based on conversations with rural utility executives who cited low property values as a deterrent to solar. The reasoning was that homeowners with a residence that has a value of around $150,000 would not invest in a $30,000 solar system as it would be such a high percentage of their property value. Property Value was not significant in the bivariate regression, but did have significant and negative correlation in the multivariate models. The small coefficient scores for home ownership and median home values indicate that they may not actually have a large impact on the capacity of solar in any one region.

Another unexpected result was the decline of installed solar capacity as electric rates rose. For every one cent rise in electric rates, watts per capita declined by 1.8 watts. Higher costs of electricity make solar more economically viable, as the systems are paid off more quickly due to a higher value of energy sold back to the grid. This result was puzzling in the bivariate regression, but in the multivariate regression models the variable ended up being non-significant.

Most surprising, yet also the most encouraging is the negative coefficient on Political and Climate Change score across all four multivariate models. This means that Republican leaning areas that oppose carbon regulation have a higher per-capita installed solar capacity than DFL, carbon regulating areas. This does not mean that it is indeed Republicans installing solar in those areas – this analysis does not look at individual system characteristics. Solar, and other forms of renewable electricity generation have traditionally been perceived as being supported by politically left-leaning areas, especially those who prioritize environmentalism. What these regressions indicate, however, is that in Minnesota solar capacity occurs at a higher per capita basis in more conservative areas.

Recommendations

Minnesota state policy is "to give the maximum possible encouragement to cogeneration and small power production consistent with protection of the ratepayers and the public."[29] This is further evidenced by the small scale solar carve out in the Solar Energy Standard of 2013 and creation of state run incentive programs like Made in Minnesota. The following recommendations are based off the state's desire to increase the amount of solar energy, and in particular small scale distributed solar energy. Since demographic figures are impractical to change as a method of encouraging solar generation, the recommendations are based off of the utility level regressions, supported by findings from the zip code level regression.

[29] MN Statute 216B.164 Subd. 1

1. **Increase number of utility led incentive program.** Both the utility level and zip code level regression indicate that the presence of an incentive program has a large and positive impact on the amount of installed solar capacity. Changing state law to have a state run incentive program, or requirement for all utilities to offer incentives for solar is currently politically infeasible. However, cooperative and municipal utilities do not have to go through regulatory approval with the public utilities commission, or obtain permission from the legislature. Their boards could implement policies which would encourage solar and provide a way for the utility to institute size to load ratios for their solar customers without changes to net metering statute. Utilities also must develop a Conservation Improvement Program (CIP), and a solar incentive program is one of the possible uses for this money. Several utilities throughout the state are already using some of their CIP dollars towards solar incentive programs. As the zip code level regressions indicated, solar is actually more prevalent in regions that lean Republican, which are also often areas of rural Minnesota served by municipal and cooperative utilities. Incentive policies may not result in the backlash that utility boards or legislators fear.
2. **Reconduct analysis on Community Solar Garden and DG Fee policies.** Time series data, or reconducting similar regression models in future years may be a more accurate way of determining the impact of these policies. For the DG Fees, there is a strong likelihood that the regression model is picking up either a reverse causality or spurious correlation, as a policy that imposes additional charges on solar customers is an improbable driver of DG growth. If areas with DG fees continue to experience higher amounts of per capita growth, it could also be an indication that other factors within those specific regions have a stronger impact that the presence of a monetary disincentive.
3. **Information Availability and Dissemination.** A large, but easily solvable problem facing the development of forward looking energy in Minnesota is information asymmetry. Interested parties throughout the state lack common sources of information about where solar development is happening and in what quantities. While the annual reports used to compile the data for this report have been collected since 2008, there has not been a concentrated effort to assemble, analyze, and disseminate this information across all stakeholder groups.
    a. Hold state agency led informational session for all Minnesota utilities annual that summarize data reported to the state. Use these sessions to engage utility stakeholders on questions, concerns, and improvements to data collection. This will help synchronize data availability. In the past, Minnesota Public Utilities Commission staff have held informational sessions on regulatory matters throughout the state for telecommunications utilities. A similar approach could be used with cooperative and municipal utilities. Staff could give a short presentation on data, and then answer questions on distributed generation from local utility boards and operations staff. This would also serve as an important relationship building tool and help connect regulators with utilities located in rural parts of the state.
    b. Create a centralized repository of information, solar related materials, and interconnection packets for all utilities. Since many customers looking to install solar go to utilities first, it is important to have accurate, up to date information readily

available. This way, utilities can easily access non-biased information that directs their customers towards workable solutions. The Department of Commerce is required by statute[30] to periodically release compiled information from the annual Distributed Generation Interconnection Reports. This should take higher priority given the importance that non-utility parties play in regulatory proceedings. The Minnesota Public Utilities Commission can also do a better job of having consumer digestible information about solar policies on their website.

While these recommendations are directed towards Minnesota's electric utilities and policy makers, they can be generalized to other states. Information asymmetry is not a unique problem, stakeholders throughout the country deal with imperfect information. State agencies can implement policies to distribute the information they collect to interested parties through online systems. Public Utility Commission websites should have sections on solar and other forms of distributed generation where consumers can easily access relevant interconnection and rates policies.

The ability to implement an incentive program will also vary state by state, based on the political climate and regulatory structure. For unregulated utilities, the ability to implement incentive programs outside of the legislative process is an option to encourage solar and create forward looking energy policies.

Conclusion

The convergence of state and national policies, along with steep declines in the cost of solar components and installation has resulted in the rapid growth of distributed generation interconnections throughout Minnesota's utilities. At this early stage of solar growth, there are not definite demographic characteristics that define high solar growth areas. Utility policies are a better indicator, especially where an incentive program is present. Other policies are too new to determine whether they are having an impact, or whether they are a reaction to solar growth. While DG penetration remains quite low throughout the state, planning for higher amounts of interconnections will ensure a smooth transition to a new type of electrical grid.

[30] 216B.1611 Subd. 3a (b)

Appendix A: Minnesota Renewable Energy Policies

	Policy Details	Implementer
Renewable Electricity Production Tax Credit (PTC)[31]	2.3¢ kWh tax credit through 2019, with drawdown	Federal
Business Energy Investment Tax Credit (ITC)[32]	30% tax credit, 12/31/19 – solar phase out begins, 10% from 2022 onward 12/31/16 – wind phase out begins, 12/31/19 expiration	Federal
REAP Grants[33]	Grants for agricultural and rural businesses to install renewable energy and energy efficiency	USDA
Renewable Energy Standard[34]	30% by 2020 (Xcel Energy) 25% by 2025 (all other utilities)	State of Minnesota
Solar Energy Standard[35]	1.5% by 2020 (IOUs) 10% goal by 2030	State of Minnesota
Made in Minnesota[36]	Production credit for solar equipment manufactured in MN, fund created by participating IOUs	Minnesota Department of Commerce
Net Metering[37]	1MW Cap (IOUs) 40 kW Coops/Municipal Utilities	State of Minnesota
Value of Solar Tariff[38]	Alternative to net metering for small solar	State, Utility
Municipal Solar Incentives	Various, both production and installation based	Utility
Solar*Rewards	Production based incentive for under 20 kW solar PV systems	Xcel Energy
SolarSense	Reward program with per kW reimbursement	Minnesota Power
POP Solar	Incentive program for public entities to install under 20 kW	Otter Tail Power
Community Solar Gardens	Allows anyone to participate in solar, Xcel has large program, others run their own gardens	Utility

31 "Renewable Electricity Production Tax Credit (PTC)." *DSIRE*. http://programs.dsireusa.org/system/program/detail/734.
32 "Business Energy Investment Tax Credit (ITC)." *DSIRE*. http://programs.dsireusa.org/system/program/detail/658.
33 "USDA – Rural Energy for America Program (REAP) Grants." *DSIRE*. http://programs.dsireusa.org/system/program/detail/917
34 "Renewable Energy Standard." *DSIRE*. http://programs.dsireusa.org/system/program/detail/2401.
35 "Renewable Energy Standard"
36 "Made in Minnesota Solar PV Incentive Program." *DSIRE*. http://programs.dsireusa.org/system/program/detail/5418.
37 "Net Metering." *DSIRE*. http://programs.dsireusa.org/system/program/detail/282.
38 "Value of Solar Tariff." *DSIRE*. http://programs.dsireusa.org/system/program/detail/5666.

Appendix B: Installed DG Capacity by Utility, as of 2016[39] [40]

Utility Name	Type	Sales (MWh)[41]	Customers[42]	Solar Capacity (kW)	# Solar Facilities
State Total		**65,321,013**	**2,649,072**	**36,222.901**	**2,861**
Adrian Public Utilities	Muni	13035	633	0	0
Agralite Cooperative	Coop	228204	5177	55.84	4
Aitkin Public Utilities	Muni	35734	2031	0	0
Alexandria Light & Power	Muni	284521	9683	0	0
Arrowhead Electric Coop, Inc	Coop	66465	4132	138.81	26
Austin Utilities	Muni	335681	12328	132.175	14
Bagley Public Utilities Commission	Muni	24022	757	0	0
Barnesville Municipal Power	Muni	21301	1317	0	0
Beltrami Electric Coop, Inc.	Coop	364556	20691	219.13	16
BENCO (Blue Earth Nicollet Faribault Coop)	Coop	317592	15929	255.83	20
Benson Municipal Utilities	Muni	34319	1831	0	0
Biwabik Public Utilities	Muni	6210	688	-	-
Blooming Prairie Public Utilities	Muni	26448	1090	0	0
Blue Earth Light & Water Dept	Muni	55876	1994	-	-
Brainerd Public Utilities	Muni	180256	7946	31.28	6
Breckenridge Public Utilities	Muni	37509	1839	0	0
Brown Co Rural Electrical Assn	Coop	139999	4148	355.675	17
Brownton Municipal Light & Power	Muni	4568	406	-	-
Buhl Public Utilities	Muni	7386	610	0	0
Ceylon Public Utilities	Muni	2437	258	-	-
City of Ada	Muni	19630	1058	-	-
City of Alpha	Muni	1405	76	-	-
City of Alvarado	Muni	4053	185	-	-
City of Anoka	Muni	277458	11847	12.2	2
City of Arlington	Muni	15896	1130	-	-
City of Baudette	Muni	20494	753	-	-
City of Bigelow	Muni	1218	121	-	-
City of Brewster Light & Power	Muni	4012	262	-	-
City of Buffalo	Muni	110964	5893	0	0
City of Caledonia Electric Dept.	Muni	25049	1654	0	0
City of Chaska	Muni	350781	9903	233	3
City of Dunnell	Muni	936	109	-	-
City of Ely - Ely Utilities Commission	Muni	37023	2030	-	-
City of Granite Falls	Muni	28867	1585	10	1

[39] Annual Distributed Generation Reports, MN Department of Commerce, Docket No. E-999/PR-17-10.
[40] "-" indicate utilities that did not file a report in 2016.
[41] EIA Form 861
[42] Ib.

City of Harmony	Muni	9618	657	-	-
City of Henning Electric Dept	Muni	8851	472	0	0
City of Jackson	Muni	46980	1974	0	0
City of Kandiyohi	Muni	3863	274	-	-
City of Kasota	Muni	3256	344	-	-
City of Kasson	Muni	29416	2494	0	0
City of Luverne	Muni	80480	2532	8.25	1
City of Mabel	Muni	5030	470	-	-
City of NewFolden	Muni	3420	227	-	-
City of Nielsville	Muni	545	57	-	-
City of North St Paul	Muni	69486	6485	-	-
City of Olivia	Muni	27858	1266	-	-
City of Peterson Electric System	Muni	1263	161	0	0
City of Randall Electric	Muni	4759	352	0	0
City of Round Lake	Muni	3574	225	-	-
City of Rushford	Muni	13934	894	-	-
City of Rushmore	Muni	1954	213	-	-
City of Spring Grove	Muni	15177	808	-	-
City of Staples	Muni	21703	1210	0	0
City of Two Harbors	Muni	26702	1872	0.57	1
City of Tyler	Muni	11102	748	-	-
City of Warren	Muni	17000	927	-	-
City of Whalan	Muni	354	38	-	-
City of Winthrop	Muni	14832	787	-	-
Clearwater Polk Electric Coop	Coop	69817	4402	114	7
Connexus Energy	Coop	1947518	129441	423.51	55
Cooperative Light & Power	Coop	95342	6037	116.72	20
Crow Wing Coop Power & Light, Inc.	Coop	564455	43202	248.555	32
Dakota Electric Assn	Coop	1792315	103977	808.45	77
Delano Municipal Utilities	Muni	56970	2681	0	0
Detroit Lakes Public Utility	Muni	186290	7166	4.32	1
East Central Energy	Coop	869881	53477	462.395	56
East Grand Forks Water & Light Dept.	Muni	157442	4338	0	0
Eitzen Light and Power	Muni	1996	153	-	-
Elbow Lake Municipal Power	Muni	17185	991	0	0
Elk River Municipal Utilities	Muni	282265	10499	25.95	5
Fairfax Municipal	Muni	11439	738	0	0
Fairmont Public Utilities	Muni	142562	5817	0	0
Federated Rural Electric Assn	Coop	381956	6685	76.87	6
Fosston Municipal Utilities	Muni	34119	896	-	-
Freeborn-Mower Coop Svcs	Coop	329107	20966	533.36	27
Gilbert Water & Light	Muni	10271	982	-	-
Glencoe Light & Power Commission	Muni	77075	2766	58.32	5

Goodhue County Coop Electric Assn	Coop	91435	5006	269.7	18
Grand Marais Public Utilities	Muni	22537	1228	36.83	3
Grand Rapids Public Utilities Commission	Muni	168422	7229	125.69	9
Grove City Electric Dept	Muni	8076	510	0	0
Halstad Municipal Utilities	Muni	9015	335	-	-
Hawley Public Utilities	Muni	20286	1158	-	-
H-D Electric Coop, Inc	Coop	133	11	0	0
Heartland Power Coop	Coop	852	40	0	0
Hibbing Public Utilities Commission	Muni	119529	8265	0	0
Hutchinson Utilities Commission	Muni	290170	7088	490.5	4
Iowa Lakes Electric Coop	Coop	440	22	0	0
Itasca-Mantrap Coop Electric Assn	Coop	206562	11612	44.604	11
Janesville Municipal Utility	Muni	11883	1464	0	0
Kandiyohi Power Coop[43]	Coop	145467	8239	149.75	20
Keewatin Public Utilities	Muni	5289	510	-	-
Kenyon Municipal Utilities	Muni	15980	965	0	0
Lake City Utility Board	Muni	143839	3197	10.64	1
Lake Country Power	Coop	598279	48631	256.57	51
Lake Crystal Municipal Utilities	Muni	15668	1204	13	1
Lake Park Public Utilities	Muni	8416	515	-	-
Lake Region Electric Coop	Coop	424784	27290	101.72	14
Lakefield Municipal Utilities	Muni	14401	1181	0	0
Lanesboro Public Utility	Muni	6240	618	0	0
Le Sueur Municipal Utilities	Muni	94363	2223	-	-
Litchfield Public Utilities	Muni	123491	3217	0	0
Lyon-Lincoln Electric Coop, Inc.	Coop	89642	3946	66.06	2
Madelia Municipal Light & Power	Muni	27034	1220	0	0
Madison Municipal Utilities	Muni	16852	947	0	0
Marshall Municipal Utilities	Muni	587485	6586	189.1	5
McLeod Coop Power Assn	Coop	184680	6617	110.38	8
Meeker Coop Light & Power Assn	Coop	172883	8782	303.42	14
Melrose Public Utilities	Muni	112908	1687	0	0
Mille Lacs Electric Coop	Coop	192670	14969	79.31	12
Minnesota Power Co	IOU	8424680	145033	2263.75	186
Minnesota Valley Coop Light & Power Assoc	Coop	196675	5267	61.11	5
Minnesota Valley Electric Coop	Coop	778478	40906	234.14	20
Moorhead Public Service	Muni	429963	17673	17.762	5
Moose Lake Water & Light Commission	Muni	35459	998	-	-
Mora Municipal Utilities	Muni	55077	1822	-	-
Mountain Iron Water & Light Dept	Muni	23720	1247	-	-
Mountain Lake Municipal Utilities	Muni	24620	1044	21.4	2

[43] Kandiyohi has not submitted its 2016 data; numbers are from 2015

Nashwauk Public Utilities	Muni	11514	648	-	-
New Prague Utilities Commission	Muni	65385	2560	0	0
New Ulm Public Utilities	Muni	191207	7210	125.71	11
Nobles Cooperative Electric	Coop	174356	6731	132.9	7
North Branch Municipal Water & Light	Muni	26288	1964	10.78	2
North Itasca Electric Coop	Coop	50062	5347	0	0
North Star Electric Coop	Coop	109269	6427	8	2
Northwestern Wisconsin Electric Co	IOU	517	83	0	0
Ortonville Light Department	Muni	27317	1340	0	0
Otter Tail Power Co	IOU	2388074	60232	259.415	23
Owatonna Public Utilities	Muni	351330	11772	34.82	4
Peoples Cooperative Service	Coop	279448	17915	850.222	59
Pierz Utilities	Muni	10113	755	0	0
PKM Electric Coop, Inc	Coop	105805	3717	0	0
Preston Public Utilities	Muni	12963	891	0	0
Princeton Public Utilities	Muni	52873	2511	0	0
Proctor Public Utilities	Muni	23871	1429	-	-
Red Lake Electric Coop	Coop	117104	5368	0	0
Red River Valley Coop Power Assn	Coop	133076	4898	0	0
Redwood Electric Coop	Coop	107859	4413	123.55	12
Redwood Falls Public Utilities	Muni	65595	2900	90.72	2
Renville-Sibley Coop Power Assn	Coop	167585	1887	421.31	15
Rochester Public Utilities	Muni	1199390	51142	832.958	72
Roseau Electric Coop	Coop	160151	6415	0	0
Roseau Municipal Water & Light	Muni	38832	1345	-	-
Runestone Electric Assn	Coop	223083	14054	143.34	14
Sauk Centre Public Utilities	Muni	60826	2285	0	0
Shakopee Public Utilities	Muni	405078	16847	-	-
Shelly Municipal Light Dept	Muni	1219	122	-	-
Sioux Valley Energy	Coop	116573	3254	37.66	3
Sleepy Eye Public Utility	Muni	45598	1875	7.1	2
South Central Electric Assn	Coop	205133	4693	232.43	13
Spring Valley Public Utilities Comm	Muni	19107	1329	0	0
Springfield Public Utilities Comm	Muni	22810	1195	22.02	4
St. Charles Light & Water	Muni	17532	1836	-	-
St. James Municipal Light & Power	Muni	54501	2218	0	0
St. Peter Municipal Utilities	Muni	92364	4231	46.8	2
Stearns Coop Electric Assn	Coop	502225	25879	361.41	24
Steele-Waseca Coop Electric	Coop	285510	11310	303.182	20
Stephen Electric Dept	Muni	8354	388	-	-
Thief River Falls Municipal Utility	Muni	140208	4838	-	-
Todd Wadena Electric Coop	Coop	157275	8557	89.86	11
Traverse Electric Coop, Inc	Coop	51499	1897	0	0

MiEnergy Electric Coop	Coop	288901	15685	555.86	34
Truman Public Utilities	Muni	10805	675	-	-
Virginia Dept. of Public Utilities	Muni	111575	5199	37.65	4
Wadena Light & Water	Muni	67797	2388	2.1	1
Warroad Municipal Light & Power	Muni	56950	890	-	-
Waseca Utility	Muni	59151	4166	40.72	2
Wells Public Utilities	Muni	17861	1359	0	0
Westbrook Public Utilities	Muni	7069	507	0	0
Wild Rice Electric Coop	Coop	255651	14007	153.01	15
Willmar Municipal Utilities	Muni	270551	9135	8	2
Windom Municipal Utilities	Muni	64561	2432	20	1
Worthington Public Utilities	Muni	213566	5347	0	0
Wright-Hennepin Coop Electric Assn	Coop	875335	49668	135.1	10
Xcel Energy[44]	IOU	30310911	1259609	21965.628	1697

[44] Xcel submitted its 2016 capacity data as protected, numbers are from 2015 report

Appendix C: Data Sources

Data Set	Publishing Organization	Location of Data Download	Vintage	Variables	Notes
Annual Distributed Generation Interconnection Report	Minnesota Department of Commerce, Minnesota Public Utilities Commission	eDockets: Docket No.	2017	Solar Capacity (kW), Number of Solar Facilities	Compiled by Hanna Terwilliger, June 2016 and March 2017
Annual Qualifying Facilities Report	Minnesota Public Utilities Commission	eDockets: Docket No.	2017	Solar Capacity (kW), Number of Solar Facilities	Compiled by Hanna Terwilliger, June 2016 and March 2017
Annual Report on Cogeneration and Small Power Production	Minnesota Public Utilities Commission	eDockets: Docket Nos. E999/17-09 E999/16-09	2016, 2017	DGFee Dummy	
Electric Utility Service Areas, Minnesota	Minnesota Public Utilities Commission, Minnesota Geospatial Information Office	Minnesota Geospatial Commons	2015	Utility Service Area	
American Community Survey, 2011-2015	U.S. Census Bureau, Metropolitan Council	Minnesota Geospatial Commons	2011-2015	Population, BachelorsorGrad, MedianHHIncome, Median Home Value, PercentOwned	
ZIP Code Tabulation Areas, 5-digit (ZCTA5), Minnesota	U.S. Department of Commerce, U.S. Census Bureau, Geography Division	Minnesota Geospatial Commons	2010	Zip, Service Zip	
Yale Program on Climate Change Communication	Yale Program on Climate Change Communication	Yale Program on Climate Change Communication	2016	Political CC Score	Combined with Minnesota elections data
Minnesota House of Representatives Election Results	Minnesota Secretary of State	Minnesota Legislature	2012, 2014, 2016	Political CC Score	
Utility Operational Data, EIA-Form 861	US Energy Information Administration	US Energy Information Administration	2016	Average Electric Rate, Number of Customers	Some numbers filled in from Annual Electric Utility Reports, Minnesota Public Utilities Commission
Utility Websites		Various Minnesota Utility Websites	2017	CSG Dummy, Incentive Dummy	Data compiled Jan – March 2017